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CORK OAK IN THE SOUTHEAST

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CORK OAK (*Quercus suber L.*) is an Old World tree that has possibilities as a farm tree crop in the southern part of the United States. This tree is the common commercial source of cork, a raw material that is essential for many civilian and military purposes. The United States, in normal times, imports annually in the vicinity of a quarter-billion pounds of cork, which is valued at 2 to 5 million dollars. Our imports constitute approximately 40 per cent of all the cork entering into world commerce. The importance of assuring a domestic supply of this strategic material during war periods, when the foreign supply may be endangered, if not entirely cut off, has been a leading consideration in stimulating interest in domestic cork oak culture from the time of the first successful introductions in the 1880's to the present.

An equally important consideration from the viewpoint of national economy is the usefulness of cork oak as a desirable hillculture crop for sloping farm lands. The development of tree crops that are adapted to culture on hilly lands and that yield a profitable cash return is a fundamental land use need in this country. Land-capability surveys in the possible cork oak areas of the United States reveal that a considerable amount of land on farms could be best protected from soil erosion and destruction of soil fertility by planting to a permanent tree cover.

The potential cork oak areas of the United States are confined, according to available evidence, to the southern part of the country, principally to California and the southeastern coast States from Virginia to Louisiana. Several of the adjoining States, such as Texas, Arizona, and Oregon, may also offer limited opportunity for cork oak culture. Because of this country's vulnerable position as regards cork supplies during war times, and the possibilities of cork oak as a farm tree crop, considerable interest has recently developed in testing the feasibility of its culture on an intensive scale, and considerable numbers of cork oaks are being planted under Federal, State, and private sponsorships. Basic information to guide these developments is available primarily only for California, as a result of several studies made during the past decade. The information given in this report is the best available knowledge on the growth and adaptability of cork oak for the Southeastern planting area.

SUGGESTIONS FOR GROWING CORK OAK ON FARMS IN THE SOUTHEAST

This information is based on the survey described in the main text of the publication and on demonstration plantings made by the Soil Conservation Service.

RANGE AND SITE REQUIREMENTS The present known climatic range (fig. 1) has been determined through plantations and climatic studies. The best guides for selecting suitable planting areas within this range are:

1. Select upland sites. The water table should be deeper than 8 feet.
2. Select soils with a sandy or sandy loam surface. Soils with a clay surface are doubtful. Texture of the subsoil is immaterial.
3. Select non-calcareous soils.

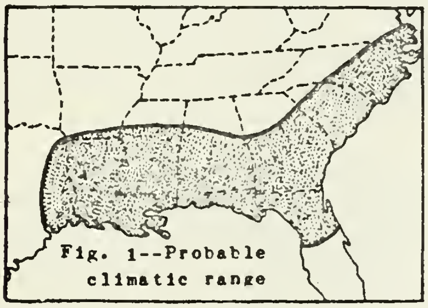

Fig. 1--Probable climatic range

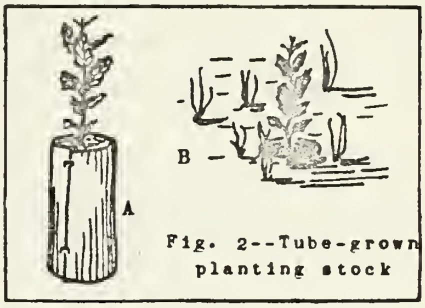

Fig. 2--Tube-grown planting stock

WHERE TO PLANT Suggested locations and combinations with other crops suitable for plantings on farms are:

1. Steep or eroded areas requiring retirement to tree cover for adequate soil protection, provided the topsoil is sandy or sandy loam.
2. Pastures requiring widely spaced trees for shade.
3. Permanent hay or small-grain fields.
4. Fence lines, roadsides, and farm lanes.
5. Poorly-stocked pine woods.
6. Home sites.

PLANTING STOCK Information on sources of planting stock can be obtained from the State Forestry Department, the County Agent, or the Soil Conservation Service. The most satisfactory planting stock is produced by sprouting the acorns in heavy paper tubes containing a mixture of soil and peat (fig. 2, *A*). The tubes are set out in May or early June when the seedlings are 4 to 6 inches tall (fig. 2, *B*). In this way the roots are not disturbed in field planting. Direct seeding with acorns may be successful, provided rodent danger is absent, the ground is free of competing vegetation, and the acorns can be watered in event of drought. Bare-root transplanting, as commonly practiced with other trees, often results in poor survival unless very carefully done, because cork oak is an evergreen and has a long taproot that is easily broken.

HOW TO PLANT Space trees approximately 40 feet apart. If the trees are planted closer, provision muxt be made for future thinning. Room for the development of a broad vigorous crown and a large stem is essential. Crowded trees grow slowly in diameter and produce less cork. A simple method of preparing open fields for planting is to disk out contour bands 6 or 8 feet wide and 40 feet apart, with the wide intervening strips left in some protective vegetation, such as hay. In places where disking is not practical, each planting spot shou'd be prepared by hoeing out a 4 to 6 foot circle to remove competitive weeds such as Bermuda grass. Planting holes for tube-grown seedlings can be dug conveniently with a post-hole digger. After setting the tube in the ground,

replace the soil and water the seedling well. Woods' soil or a teaspoonful of commercial fertilizer placed in the hole at the time of planting is desirable. A pine bough or palmetto fan on the south side of the seedling for shade, promotes survival.

CARE OF PLANTATIONS In established plantations growth rate is stimulated by soil and water conservation measures, such as mulching or ground-cover crops. Occasional fertilization promotes growth, but heavy liming is probably harmful. In the case of field or orchard-grown trees the intervening space should be devoted to pasture, hay, grain, or other low-growing crop. Intercropping should be on the contour in order to reduce soil depletion and to conserve moisture. Where livestock is present, the trees should be protected until they are beyond the reach of grazing animals. Grazing must be controlled to avoid the detrimental effect of trampling and exposure of tree roots near the surface. Where planted in the woods, along roadsides, and in similar locations, competing vegetation should be removed while the trees are small, and they should be kept free of dense overhead shade at all times. Where necessary, the trees should be pruned to produce a single clean stem 10 to 12 feet long. With reasonable attention, cork oaks are relatively free of disease, being comparable to the native oaks in this respect.

GROWTH RATE Height growth averages 1 to 2 feet per year until the trees are 30 to 40 feet tall, and the maximum height is 50 to 60 feet. Diameter growth averages ½ inch per year until the trees are about 2 feet in diameter, but trees may eventually reach 40 inches or more in diameter. Open-grown trees reach 6 inches diameter, which is a minimum for the first harvesting of cork in an average of 13 years, although this will vary greatly with the quality of the site.

CORK PRODUCTION Cork is obtained by carefully stripping the tree to a height of 3 feet at the first harvest. Subsequent strippings are made at 10-year intervals, and the height of stripping is increased until 8 to 10 feet of the trunk are stripped at each harvest. Yields average 20 to several hundred pounds per tree at each harvest, according to tree size. A 15-inch tree may conservatively be expected to yield about 50 lb. of cork, with a greater harvest 10 years later. Cork on trees in the Southeast is in general similar to that produced in Europe. Ground-cork sheets have been successfully manufactured from American cork although careful evaluations have not been made. No market value for domestic cork has been established. Before World War II the market value of imported corkwood averaged 2 to 3 cents per pound.

STRIPPING OPERATIONS Only experienced men should be allowed to do this work, since improper harvesting can kill the trees. When the plantations now being established are ready for the first harvest, it will be possible to determine proper cork stripping methods for the Southeast.

SURVEY OF CORK OAK PLANTATIONS [1]

CONTENTS

INTRODUCTION

This survey of existing cork oak trees in the Southeast was undertaken in order to help guide the present planting efforts of interested agencies and individuals. The survey covered most of the known cork oaks in the Southeast, including a total of 80 older trees at 50 locations and several thousand young trees in nurseries and recent field plantings. In this report, however, little emphasis is placed on the younger trees, since they were too young to provide significant information on growth and adaptability. The older trees occurred as single specimens or groups of 2 to 6 individuals. The largest were more than 3 feet in diameter at breast height (fig. 1).

The location of the trees in relation to climate, their form, cork production, site factors associated with their development, and other relationships, provide the best data currently available for guidance in further planting. The trees existing in the Southeast represent, in a practical sense, experimentation of several decades' duration. They are the residue of earlier planting attempts, and, as such, provide information which otherwise could be acquired only through years of planned experimentation. However, it must be recognized that the study of plant growth through an exploratory approach of this nature has certain inherent shortcomings that preclude the determination of any particular point with the degree of validity and precision that is obtainable from controlled

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[1] The survey was participated in by B. S. Crandall, Division of Forest Pathology, U. S. Bureau of Plant Industry, Soils, and Agricultural Engineering, Athens, Ga. Laboratory analyses of soils were made by H. T. Hopkins, Jr., and Paul Linder under the supervision of the writer. Cooperation in locating trees and supplying data was rendered by R. A. Young, Division of Exploration and Plant Introduction, U. S. Bureau of Plant Industry, Soils, and Agricultural Engineering, Washington, D. C.; Brooks Toler, formerly State Forester, Montgomery, Ala.; D. J. Weddell, Dean, School of Forestry, Athens, Ga.; H. J. Malsberger, State Forester, Tallahassee, Fla.; F. C. Pederson, State Forester, Charlottesville, Va.; J. S. Holmes, State Forester, Raleigh, N. C.; J. Tuttle, State Forest Ranger, Vredenburg, Ala.; B. G. Sitton and H. E. Parson, U. S. Bureau of Plant Industry, Shreveport, La.; Major C. A. Rowland, U. S. A., Elgin Field, Valparaiso, Fla.; B. A. Gardner, Columbia, S. C.; G. T. Skinner, Augusta, Ga.; L. Helm, Augusta, (cont. on p.4)

experimentation. This is due to the fact that many variables influenced the trees during their lifetime, but definite information on all of these variables was not available. It was with this viewpoint as a basis that the survey was made to obtain as much sound and practical information as possible from the existing trees.

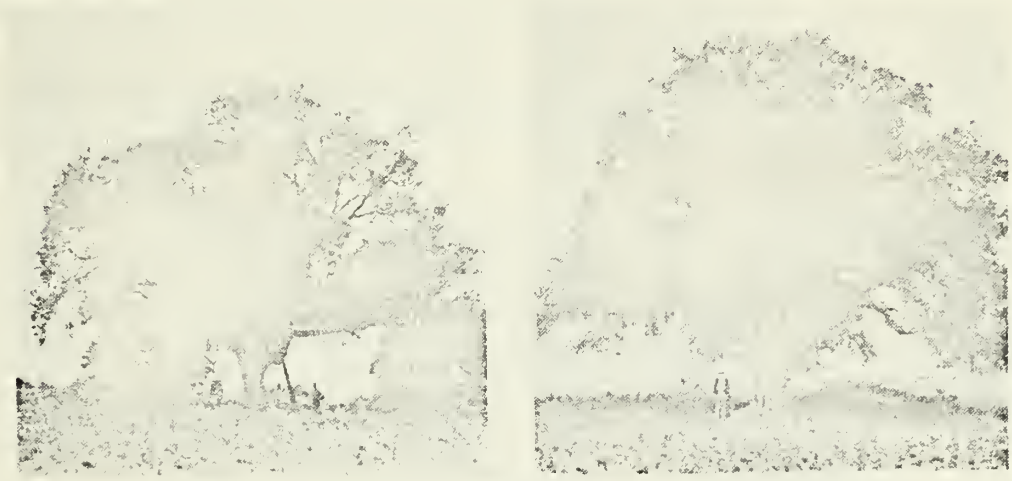

Figure 1.--Cork oak grows to mature size in the southeastern United States. Both these trees were over 3 feet in diameter at breast height and 50 feet in height. They originated from acorns distributed by the U. S. Patent Office about 1858, and were in their eighty-fifth year when these photographs were made. The tree on the left was on the Coastal Plain at Greensboro, Ala.; soil, Ruston fine sandy loam. The tree on the right was on the Piedmont plateau at Winnsboro, S. C.; soil, Wilkes sandy loam. Both trees were standing in cotton fields.

HISTORY

The earliest successful introductions of cork oak in the Southeast, so far as is known, were made in 1858 or thereabouts by the U. S. Patent Office (2, 12, 13, 15).[2] Acorns were imported from southern Spain and were distributed to numerous private cooperators in the area where it was believed that cork oak might be adaptable. Whatever records were made of this early distribution appear to be no longer available, but judging from some of the existing trees that are traceable to this introduction, it seems that

[1] (cont.) Ga.; Giles B. Cooke, Baltimore, Md.; F. Reutte, Norfolk, Va.; J. M. Fosque, Onancock, Va.; and the following officials and technicians in the U. S. Soil Conservation Service; E. G. Bolt, Paul Tabor, J. Leffelman, J. E. Gandy, P. N. Mayeaux, John D. Powell, Moses Harris, H. T. Hopkins, Jr., W. N. Watt, E. H. Peavey, F. H. Lucas, D. R. Coleman, Jr., and W. L. Colburn.

[2] Numbers in parentheses refer to literature cited.

the distributions were on a specimen-tree basis and that no groves were planted. Nine trees, which were the very oldest specimens, were traceable to this introduction, either through published records or statements of the owners. While it seems likely that some of the other old trees arose also from this source, positive verification could not be obtained. The trees that have resulted from this introduction, while few in number, are of importance because they demonstrate conclusively that cork oak will persist and grow to large size when planted under suitable conditions in the Southeast.

Subsequent distributions in units of one or a few trees are reported to have been made in the Southeast in the latter part of the '80's (8) and in 1892 (3) by the U. S. Department of Agriculture, but none of the existing trees could be definitely traced to these introductions.

Between 1911 and 1916, over 15,000 seedlings and a hundred or so pounds of acorns were distributed in the Southeast by the Division of Plant Exploration and Introduction of the former U. S. Bureau of Plant Industry, mainly to the Choctawhatchee National Forest in northwestern Florida, the Ocala National Forest in central Florida, and the Coast Land Experiment Station, Summerville, S. C. These were primarily attempts by the U. S. Forest Service to establish groves on certain problem land areas. Most of the stock, by far, failed in the first few years, so that nothing ever came out of this attempt. Of the few trees that lived past the establishment period, 4 trees still remain.

Another Government introduction in the Southeast was made in 1931, when 284 seedlings were distributed in small units to 134 cooperators by the Division of Plant Exploration and Introduction. Seedlings were sent to the following eastern and central States: New Jersey, Pennsylvania, Maryland, Ohio, Michigan, Iowa, Missouri, Kentucky, Tennessee, Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, and Texas. The largest part of the stock distributed in these States went to Florida and Texas. Reports gathered in 1941 by R. A. Young of the Division of Plant Exploration and Introduction indicate that much of the stock (which was shipped bare-root) failed to survive the transplanting. Seven, however, became established and have grown successfully.

In addition to these Governmental distributions, a commercial nursery at Augusta, Ga., has been growing and distributing cork oak for ornamental purposes for several decades. More of the trees studied in the survey were traceable to this firm than to any other source. The oldest of these trees was 40 years of age. The acorns used by this nursery have in later years, at least, been gathered from several older trees in the vicinity. The fact that this nursery has distributed many cork oaks and used this tree in land-

Figure 2.--Trunks of two picturesque cork oaks at Ocean View, Va. Their massiveness indicates well the mature size to which cork oak will grow in the Southeast. The larger of these trees was 37 inches in diameter at breast height. Soil was Norfolk sandy loam. The trees probably arose from the U. S. Patent Office distribution of 1858, although a local legend is that they were planted by pirates.

scaping probably accounts in part for the relatively large number now present in and around Augusta.

Some of the trees studied had been started by various individuals interested in propagating cork oak. For a number of the trees, however, no definite information was obtainable on their origin.

In the course of the generations since the older trees were planted, several romantic legends have become associated locally with the origin of some of these trees. An especially picturesque specimen (fig. 2), which stands a few feet from the beach at Ocean View, Norfolk County, Va., is said to have been planted by a pirate as a landmark to locate buried treasure. In central South Carolina, a common legend is that the soldiers who fought in the War of 1848 brought cork oak acorns from Mexico, whence came most of the trees of this species in the section. Factual bases do not exist for either of the stories, and it is known that at least some of the trees had a more prosaic origin.

At Onancock, Accomac County, Va., there is a cork oak tree in the base of which is embedded a concrete filling bearing the inscription "1847 by Poulson." The filling is thought to have been set at about the turn of the century, and it has not been possible to determine whether the date given is truly the year in which the tree was set. If this were so, however, the tree would be the oldest cork oak known in the Southeast and possibly in the entire United States.

Table 1 gives a summary of the origin of the mature trees by states.

Table 1.--Origin and Location of Mature Cork Oak Trees in the Southeast

Origin	Source of Seed	Number of Trees by States							Total
		Va.	N.C.	S.C.	Ga.	Fla.	Ala.	La.	
1. Commercial nursery, Augusta, Ga.	Augusta, Ga., and North Augusta, S. C.			4	16		1	7	28
2. Bur. of Plant Industry, 1931	Santa Olalla (Huelva), Spain				1	1		5	7
3. Bur. of Plant Industry, 1911 to 1916	Spain and California					4			4
4. U.S. Patent Office, 1858	Southern Spain	2	1	2	3		1		9
5. Grown by owner	Varied sources	1	2	8	2		2		15
6. Unknown	Unknown	2		8	5		2		17
Total		5	3	22	27	5	6	12	80

In addition to the older trees studied in the survey, there are also a good many thousand 1- and 2-year-old cork oaks in nurseries and in recent field plantings. These plantings originated from stock grown by the Government, the States, and private nurseries. In 1942, the Crown Cork and Seal Company also began to distribute planting stock in the Southeast.

Various methods were used to establish the trees. Those distributed in 1931 by the Bureau of Plant Industry were shipped bare-root. While some of them lived, by far the larger proportion of them failed to withstand transplanting. On the other hand, most of

the trees propagated by local individuals were started by planting acorns in small pots and then, when the trees were a few months old, setting the pots out in their permanent locations; and this method appears to be successful. Those who have raised cork oak in the Southeast emphasize the difficulty in bare-root transplanting of small seedlings because of the lengthy taproot and evergreen condition of this species. A commercial nursery that grows cork oak has had success with bare-root transplanting when the trees are 3 or 4 feet tall, provided the surface root system is carefully excavated and protected. Direct seeding has also been tried, and this has been successful when the acorns are collected immediately after they fall, for they tend to germinate rapidly or to dry out and lose their viability. Direct seeding is likely to be practical only on prepared ground where the small trees are not subjected to severe competition of native brush. No instances of successful vegetative propagation were found. Natural regeneration was observed at one location, near Columbus, Ga. At this point there were a half dozen or so small seedlings distributed in the immediate vicinity of two mature trees.

The results from the various methods of propagation that have been tried indicate that the surest and most practical of the methods is to grow the acorns in containers, such as paper tubes or punctured metal cans, and to set the young seedlings out in their permanent locations without disturbing the soil in which the roots are growing. First-year survival approaching 100 percent has been obtained in some plantations started in this way. The large number of failures with bare-root transplanting emphasizes that this method of establishing plantations is not dependable unless some means are found to avoid the heavy losses.

GROWTH RATE

Figure 3 shows height and age data for the 58 trees in 35 locations for which acceptable age information was available. The chart indicates that the major period of height growth is up to the 40th year. The average maximum height is about 45 feet. One

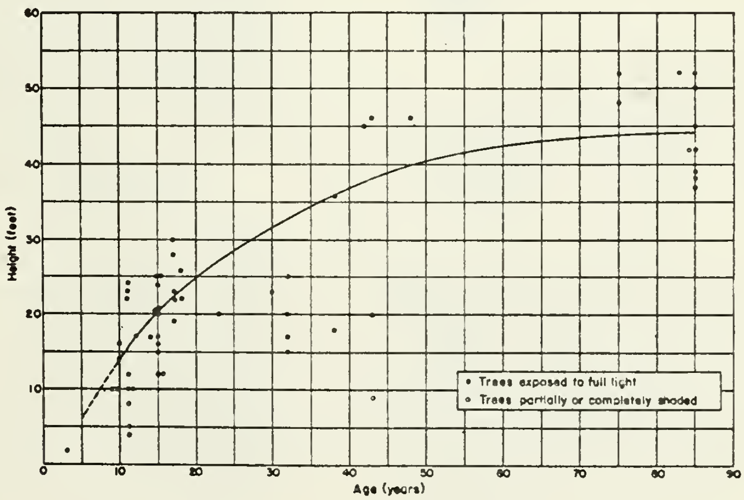

Figure 3.--Relation between age and height for cork oak trees measured in the Southeastern States. Trend line is the average for trees exposed to full light.

individual of unknown age, hence not plotted on the chart, was estimated with the hypsometer to be 57 feet tall. This was the tallest tree observed, although it was 3 feet less in height than a cork oak tree in Daphne, Ga., which in 1921 was reputed to be the largest in the United States (*4*).

It would be of interest to compare the height growth of these cork-oak trees with that of cork oak in Europe, but such data apparently do not exist in European literature. European workers have given little attention to height growth, since in practical management, diameter growth is of primary importance. However, according to Lamey (*5*, p. 3) the usual maximum height for cork oak appears to be about 40 feet and the very tallest trees up to 70 feet, from which it would appear that cork oak in the Southeast attains the normal maximum height for the species.

Examination of the data plotted on the chart shows the considerable variation in growth rate observed between individual trees. This variation permits one to characterize the height growth of each tree by a "Growth-Rate Index," which is expressed hereinafter as the percentage that the height of a given tree is above or below the average height for that age, based on the growth-rate curve shown on the chart. Such index values were calculated for all the trees for which age data were obtained, and the indexes are used in the following sections to point out apparent relationships between growth rate and various site factors.

CLIMATIC DISTRIBUTION

In figure 4, the cork oak locations in the Southeast are plotted on R. H. Mulford's Plant Growth Region map as published by Van Dersal (*14*). This map delineates the major conditions of both climate and soil. Successful growth of cork oak to mature size has been observed throughout the Upper Coastal Plain and on the Piedmont Plateau of South Carolina and Georgia, but not of North Carolina. Trees 85 years old and over 3 feet in diameter at breast height were found in

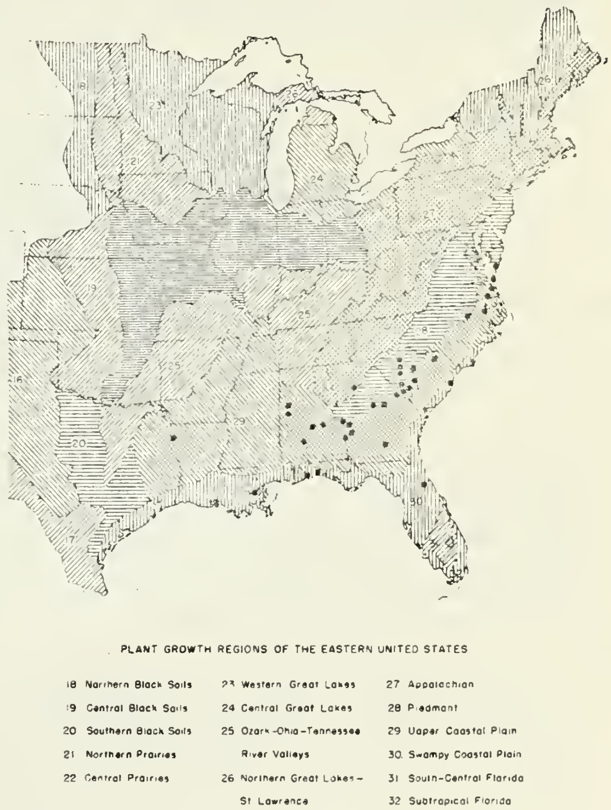

Figure 4.--Cork oak locations in the eastern United States in relation to plant-growth regions. Points where cork oaks have been observed are shown by dots. The small numerals indicate the number of planting locations represented by each dot when more than one location occurs in an area. The plant-growth regions in which established cork oak trees were found are the lower part of the Piedmont, the Upper Coastal Plain, and the Swampy Coastal Plain.

both of these regions (fig. 1). The mature size and age of many of the trees showed without doubt that cork oak grows satisfactorily in these regions.

In the Swampy Coastal Plain, cork oak trees that survived at least a decade were observed, but all of them failed to grow satisfactorily because of a high water table. This region, while climatically satisfactory, must be considered generally unsuitable for cork oak because of the prevalence of high water table conditions.

No acceptable survival and growth has been found in the Appalachian Region or in any of the other plant-growth regions of eastern United States, although records show that cork oaks have been distributed in many areas outside of the present range of surviving trees.

Table 2.—Growth Rate of Cork Oak in the Southeast in Relation to Mulford's Plant Growth Regions

Plant Growth Region	Basis		Height Growth Rate Index	
	Number of Trees	Number of Locations	Range	Average
			Percent	Percent
Piedmont Plateau	13	8	-24 to +36	+1
Upper Coastal Plain	29	18	-43 to +60	+3
Swampy Coastal Plain	11	5	-73 to -24	-44

The average growth rates for the three plant-growth regions where cork oak trees were found growing are shown in table 2. These data are based on 53 trees in 31 locations, which are all the older trees studied, exclusive of those for which age data were lacking, one tree on artificial land, and those growing in deep shade. The comparison indicates very little difference in average growth rate between the Piedmont Region and Upper Coastal Plain Region, but growth rate in the Swampy Coastal Plain Region is definitely inferior.

Another type of classification related fundamentally to climate and useful for delimiting the present range of cork oak is based on the distribution of native vegetation. Figure 5 shows the cork oak locations plotted on Shantz and Zon's map of native vegetation (9). Cork oak trees were found in areas where the following native forest trees predominated: Longleaf pine, loblolly pine, slash pine, shortleaf pine, Virginia pine (1 location), sand pine, live oak, southern red oak, and turkey oak.

The bases of comparison cited above represent a composite of climatic conditions. It is also of significance, although probably of less fundamental importance to note the lowest temperatures to which the cork oaks in the Southeast have been exposed. Data taken from local weather records and checked with the owners of the trees indicate that a number of individual cork oak trees have withstood a zero temperature, and a tree on the University of Alabama campus planted in 1934 withstood a temperature of -6° F. in 1940. The survey indicated that cork oak, although an evergreen tree, can withstand short periods of relatively low temperature, provided the general climatic conditions during the year are satisfactory.

The occurrence of existing cork oak trees in relation to plant-growth zones indicates that the climatic range to which cork oak is adapted in the Southeast is as follows in terms of geographic areas:

Virginia. Probably only the extreme southeastern part and the eastern shore.

North Carolina. Eastern half of the State.

South Carolina. Most of the State except probably not in the western quarter.

Georgia. Most of the Piedmont and Coastal Plain.

Florida. Persists in the Northern half, but most of the State probably too warm for really satisfactory growth. The high water table limits cork oak over much of the area to which it is apparently adapted climatically.

Alabama. Central and southern parts of the State; not likely to grow in the northern part or in the mountains.

Mississippi. No mature cork oak trees found; the species is probably adapted climatically to all but the northern quarter.

Louisiana. Probably most of the State, but sites will be limited in the southern and eastern portions because of the high water table.

Texas. No mature cork oak trees occur in this State; probably adapted climatically to the southern half of the Upper Coastal Plain in east Texas. The range of cork oak will be limited to the acid soils and to

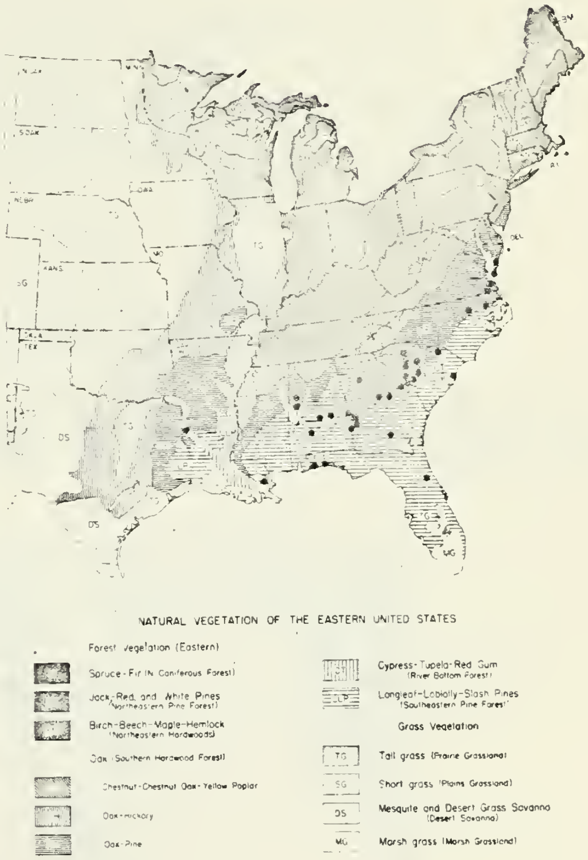

Figure 5.--Cork oak locations in the eastern United States in relation to natural vegetation. Points where cork oaks have been observed are shown by dots. The numerals indicate the number of planting locations represented by each dot when more than one location occurs in an area. The vegetation zones in which cork oak trees were found are the Southeastern Pine Forest and the Oak-Pine Forest.

areas where the water table is not close to the surface.

SITE

Comparison of growth-rate variations and site conditions indicate that shallow water table and dense overhead shade are markedly deleterious to the growth of cork oak, whereas mulching and fertilizing are beneficial. No other certain relationships between growth rate and environment were detectable.

Table 3.—Growth Rate of Cork Oak in the Southeast in Relation to Depth of Water Table

Water-Table Depth (feet)	Basis		Height Growth Rate Index	
	Number of Trees	Number of Locations	Range	Average
			Percent	Percent
2½ to 6	11	5	-73 to -24	-44
8 to 15	5	3	-11 to +18	+2
Over 15	38	24	-43 to +60	+3

Table 3 indicates consistently poor growth rate on sites where the water table was 6 feet or less beneath the ground surface. This comparison is based on 54 trees, constituting all the trees for which age data were available except those in deep shade.

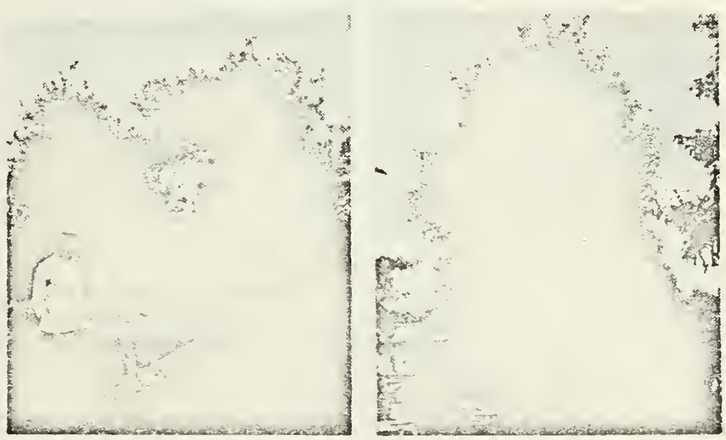

Figure 6.--Comparison between cork oak trees on unfavorable and favorable sites. The tree on the left was at a location in Florida where the water table was shallow, about 4 feet deep. The tree was approximately 30 years old yet only 17 feet tall. Growth rate index is 49 percent below average, and it was unlikely that this tree would ever reach a normal mature size. The tree at the right, in Georgia, was on a favorable site. This tree was 15 years old and 27 feet tall. Growth rate is 36 percent above average. The water table was deep and the tree had been regularly fertilized and cultivated.

The 11 trees in locations where the water table was shallow were all very poor and it is doubtful whether any of them will ever reach a normal mature size (fig. 6). They were found growing under these conditions in 5 widely separated localities, including the states of Louisiana, Florida, and South Carolina, and on a wide range of soil conditions. Six of the trees had been regularly cultivated and fertilized, and yet, despite this special care, the growth rate was consistently below average, so that the apparent factor to which the poor response was attributable was the shallow water table. Satisfactory growth was noted in the case of 5 trees that stood in locations where the water table was 8 to 15 feet deep, indicating that a water table at these depths was not deleterious.

Mechanical analyses (1) were made of the soils at the various locations and the sites were classified according to the texture of the surface soil and the profile description. It appeared of some significance that of the trees on upland locations all but one were confined to sands and sandy loams, based on mechanical analysis of the surface soil (fig. 7). Only one tree was on a soil with a clay surface horizon, and this tree was apparently making considerably below average growth although precise age data were not available. Whether cork oak is incapable of making satisfactory growth in the Southeast on sites with a heavy surface soil is difficult to say since the distribution of the trees was dependent to some extent on the frequency of the various textural grades in the region. Nevertheless, while it is certain that cork oak is adapted to grow on the sandier soils, its adaptability to soils with a loam or clay surface horizon must remain questionable pending specific planting tests on this category of soil.

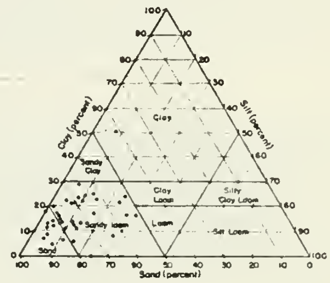

Figure 7.--Occurrence of cork oak trees on upland sites in the southeastern United States in relation to texture of the surface soil.

No other relations were detectable between growth rate and physical soil factors. The cork-oak trees seemed to be relatively nondiscriminating, as indexed by the rate of height growth, between the various soil profiles encountered. Based on the distribution of textural grades to the depth of the soil auger (approximately 3 feet), cork-oak trees were found on the following soils: Coarse sands, medium sands, sands underlain with sandy loam, sandy loams, sandy loams underlain with sandy clay, sandy loams underlain with clay, and sandy loams underlain with a clay stratum of 1 to 2 foot thickness. The average growth was somewhat poorer on sandy loams underlain with sandy clay, clay, or a clay stratum (growth rate index of +1% based on 11 locations) than on sands and sandy loams (growth rate index of +7% based on 14 locations), but the difference appeared inconsequential compared with the variations between individual locations on the same type of soil and receiving similar cultural care. The soils were also classified by soil type according to the Bureau of Chemistry and Soils classification (6), but no relationships were apparent except when a particular soil type was associated with a high water table.

Some experiments by Dr. G. S. Jones, formerly with the U. S. Bureau of Animal Industry, gives additional data on the site relationships of cork oak that tend to bear out the results given above. A portion of one of his letters, dated October 18, 1941, is of interest in this respect:

"In the fall of either 1937 or '38, I secured some cork oak acorns from the trees of Mr. Geo. McKie near North Augusta, S. C. I immediately put these in sand and on wishing to bring them to my home near Smiths Station, Ala. (about 5 mi. out from Phenix City, Ala., on Opelika Highway), the roots had become so entangled that I had much difficulty in separating them. I planted these in a protected box in the garden and got a nice stand (about 25 or 30 I suppose). I transplanted these into nursery rows the next winter, some in sandy loam soil and some in stiff clay piedmont soil. The ones put in the sandy soil grew nicely from the start but the clay soil group sent up spindling tops and until yet have made little to no growth. Some die and put out new shoots but none have made any satisfactory growth in the clay although I have not worked them or given them any attention.

"I began transplanting the ones in the sandy soil to various places on the farm and gave some to neighbors and friends who have set them in sandy loam soil. An adjoining neighbor, Mr. Busbee, set out one in his front yard and this is the nicest specimen I have. I suppose it is 8 or 9 ft. tall and looks very thrifty and the cork is beginning to show near the base. I left several in the nursery which had practically no care (maybe one or two plowings a year) and these seemed to grow very fast. I still have 6 or 8 in the rows which I have not set out and these are 3 to 5 ft. high and some show cork at the base. A few I set along roads have grown rather good except one set in a wet place with a hard pan under it has failed to thrive and has died down like the ones on the heavy clay."

Table 4 indicates that the application of mulch and fertilizer to trees on upland sites was apparently effective in promoting growth and that these treatments were generally reflected in the fertility level as shown by chemical analysis of the soil. The fastest rate of growth was found in a location where the soil had been regularly cultivated, fertilized, and mulched with cotton waste. A crop of Johnson grass formed a good ground cover. The three trees in this plantation had been given special attention by the owner and they showed a marked response, the growth rate being 53 per cent above average. The soil was a Norfolk sandy loam, which is naturally low in fertility, but the chemical tests indicated that the fertility level was relatively high as a result of the soil treatments. The second best growth rate was found in a nursery where the site had been regularly fertilized and cultivated. There was one tree in this location, a photograph of which is shown in figure 6. Cultivation and mowing, which was applied to some of the trees that received fertilizer, seemed to be relatively without effect. The trees located in mowed areas were nearly all lawn trees standing near houses, but the protection afforded by this type of location seemed to have no apparent beneficial influence. Trees standing with shrubs and young native trees had grown on the average as well as those that had been kept free of vegetative competition. This response is in accord with that in southwestern France where cork oak is grown in mixture with maritime pine (*Pinus maritima L.*). However, the four cork oak trees found growing directly beneath native trees and subjected to severe overhead shade made far below average growth. The area about three of these trees was mowed, so that severe competition of ground vegetation was not a factor.

Chemical analysis of the soil at the 27 locations where the trees were growing in full light on upland sites indicated that at least the following ranges in hydrogen-ion concentration, available soil elements (*11*), and organic matter can be tolerated by cork oak in the Southeast:

Hydrogen-ion concentration	4.4 to 6.0
Available Calcium	None to high
Available Phosphorus	Very low to high

Table 4.—Some Relations between the Growth Rate of Cork Oak in the Southeast and Cultural Care of the Site. (Based on All Trees with Age Data, Exclusive of 11 Trees on Sites with a Shallow Water Table)

Cultural Treatment	Basis		Height Growth Rate Index		Average Soil Analysis Values*							
	Number of Trees	Number of Locations	Range	Average	Org. Matter	Ca	P	K	NO_3	NH_4	Mg	pH
			Percent	Percent	Percent							
1. Soil treatments applied and competing vegetation controlled:												
A. Cultivated, fertilized, and mulched (field plantings)	3	1	+47 to +60	+53	4.6	M	H	M	O	L	M	5.0
B. Cultivated and fertilized, but not mulched (field plantings)	8	5	-14 to +36	+ 9	1.3	VL-	L	VL	O	VL	M	5.1
C. Fertilized, irrigated, and mowed (lawn plantings)	5	5	-17 to +27	+ 8	1.0	VL	L+	T	O	T	L +	5.3
2. Competing vegetation controlled but no soil treatments applied												
A. Mowed fields and lawns.	7	5	-26 to + 21	-6	1.5	T+	L	L	T-	L-	L	5.0
B. Grown up to undergrowth but no competing trees present (plantings in fields and about houses).	12	6	-43 to +19	-7	1.9	VL	L	VL	O	VL	M	5.2
3. Grown without cultural care												
A. In partial shade of other trees (codominant in woods or in mixed plantings about houses) .	8	7	-28 to +18	-1	1.8	VL	L	VL	T	VL	L	5.1
B. Growing beneath the shade of other trees (underplantings in woods and street parkway) . . .	4	3	-76 to -43	-54	1.4	T	VL+	T	O	VL-	L +	5.2

* Symbols used to indicate concentration of available nutrient elements are as follows:

H – High
M – Medium
L – Low
VL – Very Low
T – Trace
O – None

Available	Potassium	None to medium
"	Magnesium	Very low to medium
"	Nitrate nitrogen	None to trace
"	Ammonia nitrogen	None to low
"	Organic matter	0.5 to 4.6 per cent

The analysis data suggested a slight positive relationship between growth rate and the phosphate and potassium content of the soil, but there was so much variation in growth rate not accounted for by each element individually that no single one could be judged to have had a prominent influence on growth rate. The relationships were tested mathematically by assigning numbers from 0 to 5 to correspond to the 6 consecutive quick-test classes of "none" to "high" and calculating the correlations between each of the elements and the growth-rate index. The linear correlation coefficients for the three most suggestive relationships were +.206 for calcium, +.375 for phosphate, and +.303 for potassium, with .381 required for significance at the 5 percent level (25 degrees of freedom) (*10*, p. 133).

Although the content of available calcium ranged from none to high, the soils were apparently acid in all cases. In view of the fact that European experience indicates cork oak to be a calciphobe, the absence of trees on the basic soils was probably to be expected. While cork oak perhaps may not grow on the pedocal soils within its potential climatic range, it apparently will tolerate the presence of calcium on the acid soils examined in this survey.

The foregoing site analysis indicates that cork oak might be successful on a wide range of sites within its climatic province in the Southeast, provided that areas where the water table is approximately 6 feet or closer to the surface are avoided and the trees are not planted in dense overhead shade. Furthermore, the adaptability of cork oak to clay surface soils would appear questionable.

TREE FORM

The two primary tree-form characters that determine cork yield are the shape of the trunk and the diameter of the stem. Measurements on the cork oaks in the Southeast in these respects and an analysis of the factors associated with variations in these characters are therefore of significance.

Table 5 shows that most of the open-grown trees forked within the first 12 feet of stem, which is an approximate maximum height to which cork oak is stripped in Europe (*3*).

Table 5.—Frequency of Trees with Forks in the First 12-foot Length

Location of trees	Number of trees	First 12 feet	
		Forked	Single-stemmed
		Percent	Percent
In full light	45	87	13
In restricted light	20	50	50

(X^2 = 8.23, significant at 1% level)[3]

[3]Chi-square was calculated using the method described by Snedecor (*10*, p. 168) in which a correction is made for small numbers.

Comparison between the open-grown trees and the trees whose crowns were restricted by the shade of other vegetation indicates that the formation of single-stemmed individuals might be stimulated by subjecting trees in their youth to a limited amount of lateral shade.

While most of the open-grown trees forked close to the ground, a few were single-stemmed for a considerable portion of their height. Figure 8 shows an example of such variation between two trees that grew side by side near North Augusta, S. C. Diversities in growth form have been observed in Europe as well, and these observations suggest the possibility of making genetic selections from the variations found among existing trees. Experiments are now under way to find methods of propagating superior-formed cork-oak trees vegetatively.

In figure 9, the rate of diameter growth is compared with similar data for cork oak in Europe. For this purpose, data of French origin, cited by Lamey (5, p. 106), were transcribed from the metric scale into English equivalents. It is seen that the cork oak trees in the Southeast made better growth than the averages given by Lamey. This result might at first thought appear to be unexpected, but a moment's consideration will indicate this to be entirely reasonable, since the European data would presumably represent natural, average growing conditions, whereas in the Southeast an effort was probably made in planting to choose sites that were thought to be favorable and many of the trees received supplementary care. It is of some significance in this regard that a few of the trees in the Southeast were close to the trend line shown by Lamey. A reasonable conclusion from this comparison is that cork oak can be grown in the Southeast at a rate of diameter growth that is at least average for the species. For the average sites sampled, cork oak reached 6 inches diameter at breast height, which is often considered as a minimum size for the first harvest of cork in Europe (7), in approximately 13 years.

Figure 8.--Variation in growth form between two adjacent cork oak trees. The tree on the left was single-stemmed for a considerable proportion of its height and was relatively narrow-crowned, whereas the tree on the right was forked a short distance above the ground and had a much wider crown. The occurrence of such diverse forms on the same site suggests that variations in growth-form may be due partly to individual tree characteristics.

The stem diameter for trees of various heights, which is an indication of the overall taper of the stem, is shown in figure 10. Compared with our native trees generally, cork oak is characterized by a large bole for its height: that is, for a given height of tree, cork oaks have a much greater diameter at breast height than most of the native trees of the Southeast, except the live oak (*Quercus virginiana L.*), which it resembles in both stem form and crown spread.

In managing cork oak for maximum cork production, it would appear to be advantageous to stimulate development of trees with large stem

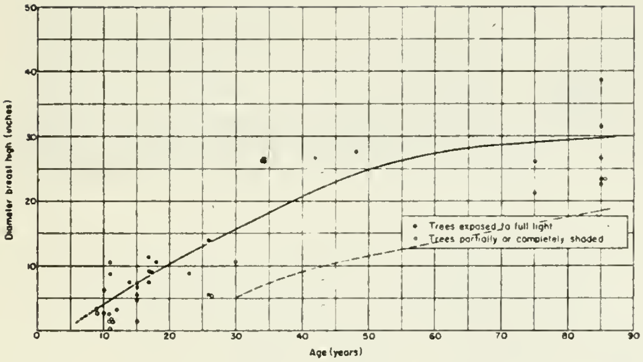

Figure 9.--Relation between age and stem diameter for cork oak trees measured in the Southeastern States. Trend line is the average for trees exposed to full light.

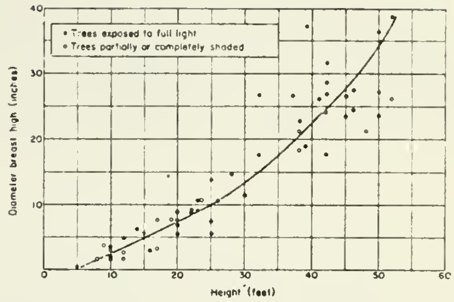

Figure 10.--Relation between height and stem diameter for cork oak trees measured in the Southeastern States (exclusive of trees forked at or below breast height). Trend line is the average for trees exposed to full light.

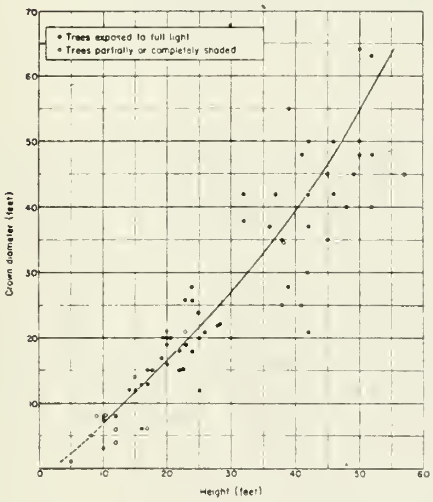

Figure 11.--Relation between height and crown diameter for cork oak trees measured in the Southeastern States. Trend line is the average for trees exposed to full light.

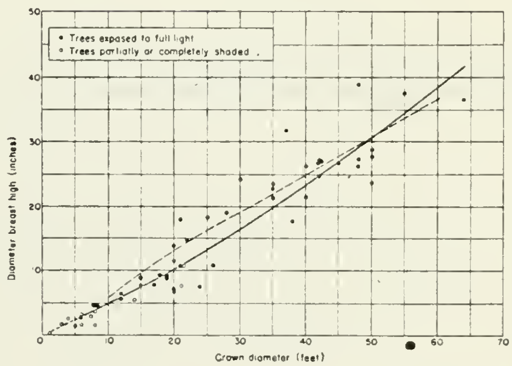

Figure 12.--Relation between crown diameter and stem diameter for cork oak trees measured in the Southeastern States. (Exclusive of trees forked at or below breast height). Trend line is the average for trees exposed to full light.

Broken trend lines in figure 9 and 12 are European data transcribed from Lamey (6)

diameter in proportion to tree height. The data show that the size of the crown is the most important single factor associated with stem diameter. Wide-crowned trees had greater stem-diameter than narrow-crowned trees of the same height. This is expressed mathematically by the correlation coefficient of stem diameter and crown diameter, when tree height is partialed out. The correlation coefficient obtained for 41 trees (which includes all the trees for which age data were available, exclusive of those that forked below breast height) was +0.70, which is highly significant.[4] This relationship indicates the importance when planting cork oak of giving the trees sufficient space to attain the maximum crown development. Figures 11 and 12, which show the average crown spread for open-grown trees of various heights and various stem diameters, indicate that trees should be spaced at least 40 feet apart upon maturity if they are not to become too crowded to make maximum diameter growth.

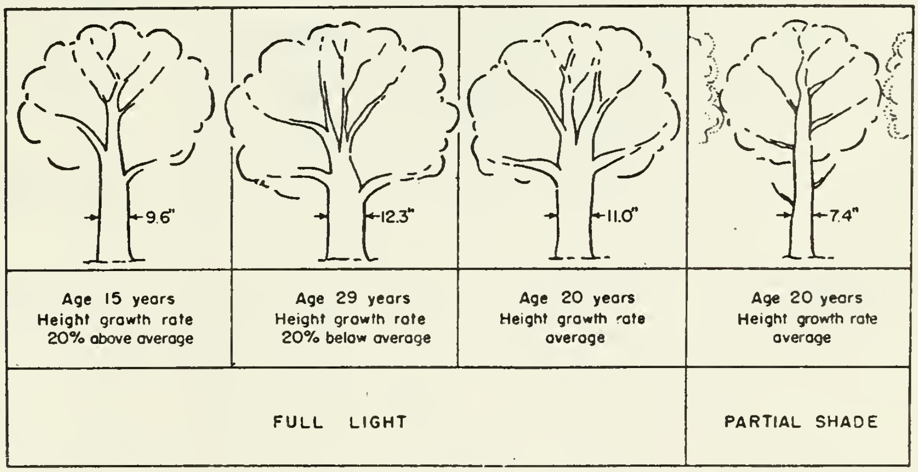

Figure 13.--Diagrammatic representation of cork oak trees showing average stem diameters associated with trees of various growth rates exposed to full and restricted lights. A tree height of 25 feet is used as the basis for the example. Stem diameter scale 3 times the scale used for height and crown diameter.

Growth rate and shade by surrounding trees markedly affect the stem and crown form of cork oak. Examples of these relationships are shown diagramatically in figure 13. These results were obtained through a study of the same 41 trees as described in the preceding paragraph. Variations in crown size and stem diameter that were unrelated to tree height were subjected to the statistical analysis presented in table 6. The table shows highly significant correlation coefficients for stem diameter and growth rate (-.52) and for crown size and growth rate (-.46). This indicates that slower-growing trees have greater crown diameter and stem diameter than faster-growing trees of the same height. Moreover, these relationships held whether the trees grew in full or restricted light (indicated by the fact that the test of the pooled regression was not significant). The trees partially shaded by surrounding vegetation have a lesser stem diameter and crown diameter than trees of equal height and age standing in full light, as shown by the high-

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[4]The correlation coefficient was calculated by the standard method (*10*, p. 123), using the deviations in stem diameter and crown diameter (expressed in percent) from the respective relationships with tree height shown in figures 10 and 11.

Table 6.--Analysis of Covariance of Crown Spread and Stem Diameter for 41 Cork Oak Trees Classified According to Light Conditions and Growth Rate.

Source of Variation	Adjusted Degrees of Freedom	Variations in Crown Spread Unrelated to Tree Height (Crown diameter deviations in Figure 13, in per cent.)		Variations in Stem Diameter Unrelated to Tree Height (Stem diameter deviations in Figure 12, in per cent.)			
		Adjusted for growth rate		Adjusted for Growth Rate		Adjusted for Crown Spread	
		Corr. Coeff.	Mean square	Corr. Coeff.	Mean square	Corr. Coeff.	Mean square
Within light groups	36	-.46*	554	-.52*	780	.68*	578
Between light groups	1		5197*		9387*		358
Sum of light groups	35		543		798		593
Difference for testing pooled regression	1		920		136		47

* Significant at the 1 per cent level.

ly significant difference between light groups. However, the reduction in stem diameter for trees in restricted light is directly associated with the reduced crown diameter. This is indicated by the part of the analysis in which the stem-diameter data are adjusted for the relationship with crown spread.

CORK

The cork oaks in the Southeast produce virgin cork (fig. 14) that is generally similar in appearance and texture to that produced on cork oak in Europe. Twenty-two trees had been partially stripped, sometimes out of curiosity and sometimes to obtain fishing corks. It was observed in these trees that smooth secondary cork formed in places where the virgin cork has been removed, provided that the stripping had not also removed the inner bark (figs. 15 and 16). This reaction is similar to that which occurs in commercial harvesting of cork in Europe. None of the trees had been regularly stripped in a way that would be analagous to commercial harvesting, nor had the cork been tested industrially, although pieces of cork had been used locally for floats on fishing lines.

Figure 14.--Virgin cork on a cork oak tree in Columbia, S. C. The rough appearance of the cork is characteristic of that produced by this species on unstripped trees.

Figure 15.--Cork on a partially stripped cork oak tree near North Augusta, S. C. Rough, virgin cork in the upper left, secondary cork in the lower right side of photograph.

Figure 17 shows the average thickness of virgin cork produced on trees in the Southeast. Based on Lamey's statements (5), the cork thickness on these trees is in the same range as that of virgin cork in Europe, although a direct comparison is not possible since European data are largely based on secondary cork for the larger sized trees. The thickness of the virgin cork was related to the diameter of the stem. Cork began to form when stems reached a diameter of approximately one-half inch and increased thereafter to a thickness of 3 inches in the largest trees observed. While the thickness of the cork was approximately related to stem diameter there was considerable variation in this respect, some trees having much thicker cork than other trees of the same diameter. Examination of data from 52 trees indicated that the

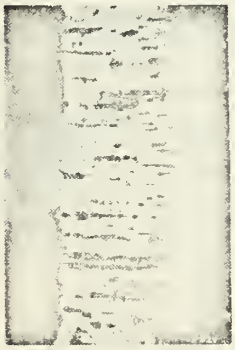

Figure 16.--A section through a piece of corkwood collected from a cork oak tree near Shelton, S. C. This piece is typical in appearance of secondary cork of a fair grade.

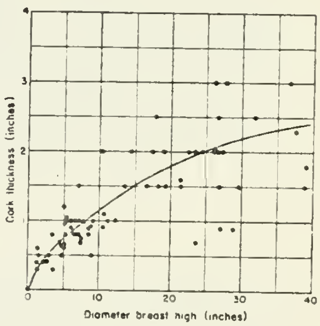

Figure 17.--Relation between stem diameter and thickness of virgin cork for cork oak trees measured in the Southeastern States.

trees with cork of greater than average thickness for the diameter of the stem were generally the individuals that had made slower diameter-growth. Based on the percentage deviations from the curves for diameter growth rate and cork thickness (figs. 9 and 17), a correlation coefficient of -0.28, which is significant at the 5 per cent level, was found between cork thickness and age, when stem diameter is partialed out. This would indicate that a slow rate of diameter growth is partially compensated for by thicker-than-average cork.

DISEASES AND INSECTS [5]

The cork oaks in the Southeastern States compare favorably with the native oaks in resistance to diseases where they are found growing on sites to which they are suited. Like all trees, they are exposed to disease from the seed stage to maturity. In some instances attacks by parasitic fungi or insects can be controlled or minimized. Fifty-seven of the cork trees, covering the present known range of the species in the Southeast, were surveyed to determine the diseases and insects that have afflicted them. About half of these trees were old mature specimens, the other half were 30 years old and younger.

ACORN DECAY

Approximately 25 pounds of acorns were examined for decay and weevils. About 10% of the acorns were found to be defective, 8% were weeviled, and only 2% of the loss was directly due to fungus and bacterial decay. Where the acorns are allowed to lie on the ground for mast, this loss is unimportant. If the acorns are collected for subsequent planting some precautionary measures are necessary. If allowed to dry out, the germinability of the acorns will be impaired. Fumigation and stratification in moist sand or moss in cold storage is suggested if the acorns are to be held for spring planting. Fall planting is probably to be preferred.

Figure 18.--*Endothia* disease on cork oak. The ends of the twigs have been killed by the action of the fungus, *Endothia gyrosa* (Schw.) Fr. The pinhead-like pustules on the bark are the fruiting bodies of the fungus; they are orange to reddish brown in color.

CANKER

The most prevalent disease on cork oaks in the Southeast is a canker on the branches apparently caused by the fungus *Endothia gyrosa* (Schw.) Fr. (fig. 18). This fungus, a close relative of the chestnut-blight organism and almost indistinguishable from it, is found in the South on suppressed and injured portions of the native oaks and as a saprophyte on some other tree species. From the disease standpoint it is relatively unimportant on the native oaks. The observations made on cork oaks indicate that on this

[5] This section has been prepared by Bowen S. Crandall, Division of Forest Pathology, Bureau of Plant Industry, Soils and Agricultural Engineering, with advice on the insect portions from the Division of Forest Insect Investigations, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration.

species it is somewhat more parasitic. On 9 of the 29 mature trees examined it was killing branches and definitely invading living tissue. The branches involved were those on the lower portion of the tree which were suppressed by the shade of the canopy above. Of the 7 trees, 25 to 30 years old, 4 contained cankers, and in two cases these cankers were on the main stem of the tree and were girdling and killing the portion above them. These two trees were growing on an unsuitable site and were making poor growth. Among the 21 trees less than 25 years in age that were examined, only one case was found, and this was a very light attack on the branches.

These observations indicate that where the tree is making poor growth from other causes, this fungus is apparently able to attack and cause girdling cankers. Otherwise, it is found attacking suppressed branches only. What the effect of this fungus will be on trees from which the cork has been stripped is problematical. This Endothia produces spores abundantly in late summer, and these will doubtless be carried to the main trunk where openings or injured areas will have been made by the decorking process. In all probability control could be obtained by applying a protective coating immediately after the cork is removed. Areas of dead tissue, caused by the levering action of the tools used in removing the bark, should be excised, painted, and given a coat of wound dressing to remove the possibility of the fungus gaining entry as a saprophyte and then spreading into healthy surrounding tissue. Some type of protective coating may be desirable also to increase the value of the second growth cork by cutting down drying and oxidation of the exposed inner bark and to help prevent casualties from the stripping process.

ROOT ROT

Meager reports from Europe indicate that the cork oak may be susceptible there to root rot caused by *Phytophthora cambivora* (Petri) Buis. The presence in the Southeast of the closely related *P. cinnamomi* Rands, a root parasite of the American chestnut, made tests of susceptibility desirable. Three seedlings that survived transplanting remained a full year in an experimental plot where the fungus was active. When dug and examined the roots were free from infection. Root rot has not been observed on the trees seen during the survey. None the less, since the cork tree does not do well on poorly drained sites, these should be avoided, as it is on such a site that root rot would be a factor.

WOOD ROTS

Five of the 29 mature cork oaks examined were badly decayed by heart rot. Probably others contained decay, of which there was as yet no external sign. Decay in the heartwood and tops of mature cork oaks is caused by fungi, probably those which are found in native oaks growing nearby. The fruiting bodies, which appear as conks or mushrooms on the trunk, produce air-carried spores which gain entry to the tree through wounds which expose the wood. Some of the loss from decay should be preventable, if pruning is done while limbs are small and large wounds are painted. The same practice should be followed in removing dead or broken branches. Very little can be done after heart rot has developed.

SLIME FLUX

A condition resembling slime flux was found on seven of the older trees and four of the younger ones. Slime flux usually develops when the exudate from a wound becomes fermented by bacteria, yeast, or fungi. In two trees that were dissected, the flux condition apparently resulted from water draining from dead areas higher up in the tree and running down the trunk under the cork layer until an opening was found. Callus formation, in the cases seen on the survey, at the point of drainage was retarded by fermentation and was stained dark by the exudate.

BURLS OR GALLS

On nine of the 29 mature trees examined, but not on the younger trees, burls were of common occurrence (fig. 19). In two cases the burls were dissected in order to determine their origin. In these two cases the burls were apparently the result of callus formation around a dead branch stub. Whether the original cause was parasitic could not be determined, but later callus growth was apparently healthy. Such burls are objectionable from the standpoint of cork production.

Figure 19. - A large burl on the trunk of a cork tree. Such burls range from small protuberances to large growths 1 to 2 feet across. The cause of burl formation is unknown.

TIP DIEBACK

A tip dieback (fig. 20), the cause of which is still undetermined although it is thought to be caused by insects, has resulted in injury to 100 percent of the seedlings in one nursery. It has been found as a serious factor in recently established plantings. Fourteen of the trees examined in the survey were more or less affected by this trouble. The young, succulent tips of branches or the terminal growth of seedlings and young trees is killed back for a distance of several inches. In very young trees this results in a lateral bud developing and resuming the terminal growth which gives the tree a crooked stem. It is possible that this dieback continuing year after year is the cause of many trees in the South being of deformed shape.

Figure 20.--Tip dieback is common on young trees. The young, tender tips die and a side sprout develops as the main shoot. This injury, apparently associated with an insect, may be an important factor in causing deformed trunks as a result of the wide angle at which the side shoot is produced.

LEAF MINERS

The leaves on 18 of the trees examined were parasitized by leaf miners. In no case has the attack been severe enough to cause any apparent injury to the tree. In the case of some of the trees grown as ornamentals, the unsightly appearance of the dead and blistered leaves caused some concern. The insect or insects responsible for the damage have not been identified but they appear to be similar, in the few instances where they have been seen, to the leaf miner found nearby in native scrub oaks. This has been identified by the Division of Forest Insects as a species of *Brachys*, a small leaf-mining beetle.

LOSS FOLLOWING CORK HARVEST

In the Southeastern States some losses, mostly of large trees, have occurred following experimental harvesting by private parties. An examination of some of these trees indicated that fungi and insects did not play a primary role, and that the underlying causes probably are of physiological origin. The losses following strippings were confined to trees that were $1\frac{1}{2}$ to 3 feet in diameter at breast height, while several smaller trees were stripped without loss. Reports (*16*) from Europe indicate that some losses following stripping may be expected. No completely

satisfactory explanation has been given for these losses, although climatic conditions at the time of stripping and low vigor of the tree itself are indicated to be factors that may influence the success with which trees are stripped. Reports from California, on the other hand, indicate that the losses from stripping trees of various sizes in that State have been negligible.

Although the losses among stripped trees in the Southeast were confined to the larger trees, actually in the normal course of selective harvest from a plantation the first cork would be harvested when the trees attain a diameter of about 6 inches at breast height. In Europe subsequent regular stripping of the new cork layer apparently can be done with little more risk than the first stripping of small trees. While there appears, therefore, to be considerable hazard in stripping large cork oak trees in the Southeast if they had not been stripped previously, no cases were found of trees that had been stripped periodically from their youth, so that the reaction of trees to regular stripping practices cannot be determined at this time.

DISCUSSION AND CONCLUSIONS

It is appropriate to evaluate this survey in relation to the practical feasibility of establishing a domestic source of cork in the Southeast. The survey points out that cork oaks have survived and grown to mature size over a wide range in the Southeast. From this, it may be concluded that the Southeast is climatically a potential cork-producing area. Further, there are soils within this larger climatic area on which cork oak trees can be grown successfully, and other soils to which they are apparently not adapted. Fortunately, the soils occupying the largest areas in the adaptable climatic zone (for example, soils of the Norfolk, Ruston, and Cecil series) are among those on which cork oak trees are growing successfully. Another point of importance brought out by the survey is that growth habit and cork formation appear generally to be normal in the Southeast, based on a comparison of tree data for cork oak in the Southeast and in its native Old World range. These are all promising results.

On the other hand, there has been practically no actual experience in growing cork oak as a crop, so that there is still much to be determined before the feasibility of its culture can be definitely ascertained. Still less is known as to the quality of secondary cork that could be produced under normal harvesting conditions. These facts need to be particularly emphasized because of the public interest that has currently developed in cork oak culture. This interest has led to a certain amount of over-optimism, that may have the effect of misleading people who are not entirely acquainted with the facts and may promote ill-advised speculation. Statements such as the following, which recently appeared as captions to newspaper articles on the subject appear particularly misleading: "Growing of Cork Oak Foreseen Major Southern Industry", "Cork Trees Help End King Cotton's Rule in Southern States". A thorough appraisal of the facts indicates that such statements are highly premature and that the eventual development of cork oak as a crop in the Southeast is still conjectural. The situation calls for systematic research to develop and prove the essential bases for such an industry. It would appear that the foundations for cork oak culture in the Southeast require consideration of the following factors at least:

1. Adaptability of cork oak to climate, soil, and other ecological factors.

2. Determination of feasible methods for establishing and managing cork oak plantations, for harvesting the cork without losses, and for producing cork of desirable quality.

3. Economic and financial desirability of cork oak culture based on comparison with other crops adapted to similar types of land use.

4. Determination of production centers, based on the availability of favorable land use areas in relation to labor and economic requirements.

From the viewpoint of these four considerations, it is apparent that the existing cork oak trees in the Southeast have furnished valuable information relative to adaptability and certain aspects of establishment and management. On the other hand, no cork oak plantations of commercial size exist in the Southeast, except a few that have been newly established on an experimental basis, and these are too young to yield definitive results. Hence, factual knowledge is largely lacking on the financial aspects of cork oak culture in this region, as well as on the broader economic factors that would determine the position cork oak culture might occupy in Southern agriculture.

Occasional mention has appeared in scientific literature on the possibility of growing cork oak in the Southeast, yet it has not been generally recognized that cork oak is adapted to a wide range of conditions in this area. Only in the last several years, as a result of the intensive effort to locate trees, has it really become evident that cork oak may have crop possibilities in this section. Yet there are a number of mature trees in the Southeast, indicating that there has been interest in the past in this tree. One may therefore well question the reasons why cork oak plantations of commercial extent have never been developed. The evidence suggests that the most important single reason has been a lack of knowledge of the essential requirements for successful establishment of cork oak in the region. Between 1911 and 1916, attempts actually were made to establish several plantations on more than a specimen tree basis. During this period, a total of 16,406 seedlings and 68 pounds of seed were distributed by the Division of Plant Exploration and Introduction of the former Bureau of Plant Industry, mainly to the National Forests in Florida.

A recent survey of the plantings reveals that only 4 trees remain of all the stock planted. This result at first glance would seem to be discouraging so far as the possibility of domestic cork oak culture is concerned. However, a careful study of the planting records and reports in the files of the U. S. Forest Service was recently made, and the conclusion from the examination was that the plantings were associated with certain local conditions which make the results inapplicable to the Southeast as a whole.

In all but one of these national forest plantings, the trees died before or shortly after they were planted, indicating that conditions were such as to preclude the possibility of their even becoming established. Contemporary records reveal that most of the acorns and seedlings failed to survive the original planting, owing to difficulties in keeping the planting stock in good condition during shipment. A small amount of the stock survived planting, but nearly all died during the first season, because of the heavy competition from native brush, rabbit injury, flooding during a high-water period, and the sites unsuitable for tree oaks.

In the one plantation where successful initial establishment was obtained (in the Choctawhatchee National Forest in west Florida), 25 pounds of acorns had been set out in January on cultivated soil of a sandy texture. The planting was made in 1911 and the trees grew well for the first few years, but by 1920 only 2 or 3 trees were still vigorous, and by 1942, when the plantation was last examined, all but 3 of the trees had died. The continued survival of these few trees over a period of 32 years indicates that the climate in this section is acceptable for cork oak. However, the trees had become completely stagnated and those that lived had made very little growth in the last 22 years.

Thus, conditions on this site were apparently such as to permit satisfactory growth only for the first few years, and this seemed attributable to the presence of a high water table, which inhibited proper root development. Auger borings showed that the water table on the area was only 3 or 4 feet deep, for the site was a part of the swampy coastal plain and was situated only a few hundred feet back from a bay of the Gulf of Mexico. It has been previously pointed out that high water table has proved consistently unfavorable for a taprooted tree such as cork oak wherever such trials nave been made in the Southeast. In addition to the high water table, another factor that contributed to the poor results was a hurricane in 1918 or thereabouts that covered the foliage with salt spray and resulted in defoliation. It therefore appears that the failure in these plantings was attributable to a complex of unfavorable local conditions not general to the Southeast; hence these trials provide no adequate basis for judging the performance of cork oak as a crop when planted in the kind of sites to which it is adapted.

The foregoing review suggests that a need now exists to determine practical and economic methods of growing cork oak through plantings of large enough size to permit experimental management and harvesting. Furthermore, it is essential that consideration be given in the future to the propagation requirements of this species inasmuch as a large part of the failure in the past has been due to unacquaintance with the fundamental factors of establishment. The survey has shown also that while the species is not demanding so far as soil fertility is concerned, care must be observed in avoiding sites to which it is not adapted. In addition, it would appear possible to increase the growth rate in plantations considerably through application of simple cultural treatments, possibly in connection with the production of intercrops during the period in which the trees are still small. Certain of the pitfalls in growing cork oak have been revealed by previous failures, and it should be possible to avoid repetition of these failures in the future. However, so little is known as yet on methods of management, including cork harvesting, on financial aspects of cork oak culture, and on the other economic factors involved, that the role cork oak culture may eventually play in southern agriculture is still highly conjectural.

LITERATURE CITED

1. Bouyoucos, George John
   1936. Directions for making mechanical analyses of soils by the hydrometer method. Soil Science 42 (3): 225-230, illus.

2. Hough, Franklin B.
   1878. Report upon forestry, prepared under the direction of the Commissioner of Agriculture in pursuance of an act of Congress approved August 15, 1876. Vol. I, 650 pp., illus.

3. Jones, J. D.
   1895. Cork oak. Pp. 9-18 in Some foreign trees for the Southern States, prepared under direction of B. E. Fernow. U. S. Dept. Agr., Div. of Forestry, Bull. 11, 32 pp., illus.

4. Lamb, George N.
   1921. American grown cork. American Forestry, 27: 15-16, illus.

5. Lamey, A.
   1893. Le Chêne-Liège, sa culture et son exploitation. 289 pp., illus. Paris.

6. Marbut, C. F.
   1935. Soils of the United States. Part III of Atlas of American Agriculture. 98 pp., illus.

7. Metcalf, Woodbridge
1929. Cork oak - A forest tree with possibilities for California. California State Department of Agriculture, Monthly Bulletin 18(10): 539-561, illus.

8. Record, S. J.
1912. Possibilities of cork oak in U. S. Hardwood Record XXXV (5): 29 pp., illus.

9. Shantz, H. L. and Raphael Zon
1924. Natural vegetation. In Atlas of American Agriculture. 29 pp., illus. Washington.

10. Snedecor, George W.
1940. Statistical methods. 422 pp., illus. Ames, Iowa.

11. Thomas, R. P., and R. C. Williams
1937. A comparison of the results of rapid tests with the amounts of available nutrients obtained by quantitative methods on Maryland soils. Soil Science of America Proceedings 1936, 1: 243-254.

12. U. S. Commissioner of Patents
1856. Report of the Commissioner of Patents for the year 1855. Agriculture. House of Representatives, Ex. Doc. 12. 488 pp., illus.

13. U. S. Commissioner of Patents
1859. Report of the Commissioner of Patents for the year 1858. Agriculture. House of Representatives, Ex. Doc. 105. 552 pp., illus.

14. Van Dersal, William R.
1938. Native woody plants of the United States, their erosion-control and wildlife values. U. S. Dept. Agr., Misc. Pub. 303. 362 pp., illus.

15. Vasey, George
1887. Report of the botanist. Pp. 69-93 in Report of the Commissioner of Agriculture for 1886. 719 pp., illus.

16. Vieira Natividade, J.
1938. Tecnica cultural dos sobreirais. II. Descortiçamento. Ministério do comércio e indústria, Junta nacional da cortiça. 71 pp., illus. Lisbon.